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LEVERAGING THE CITIZEN SCIENCE PLATFORM iNATURALIST FOR THE TARGETED COLLECTION OF NATURAL HISTORY SPECIMENS

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Abstract. Specimens housed in natural history collections provide an important record of the Earth's biodiversity and are increasingly used to address a diverse range of scientific questions. However, these collections are not random; they exhibit notable taxonomic and geographic biases, prompting calls for the development of more representative sampling strategies. The rate of new collecting is also declining. Here we present an approach that uses observation-based occurrence records from the iNaturalist platform to target specimen collecting to gaps in collections, with customisation by taxon, time period, location, and research priority. To illustrate this, we provide a case study on vascular plants in Wellington, New Zealand, which shows an increase in newly collected species for the WELT herbarium over the fiveyear period that we have been using this tool compared with previous five-year periods. This approach not only makes use of data generated by citizen scientists but also offers opportunities to engage citizen scientists in collecting, which is beneficial for ensuring the long-term sustainability of natural history collections.

Key words: iNaturalist, citizen science, herbarium, natural history collections, observation, specimen acquisition, targeted collecting, Wallacean shortfall

Introduction

Natural history collections house specimens that are an important record of the Earth's changing biodiversity over the last few hundred years. Historically specimens were obtained principally for undertaking taxonomic research. However, over the past few decades specimens have been used to address a much wider array of scientific questions in areas such as biosecurity, environmental monitoring, agriculture and public health (Miller et al. 2020, Forbes et al. 2025a). Supporting these new applications are breakthroughs in digital imaging and online data sharing, which have greatly improved access to specimens (Bakker et al. 2020), along with advances in data science and molecular techniques, such as genomics and stable isotope analysis, that have transformed how collections are used.

Despite experiencing a renaissance in use, natural history collections are increasingly at risk due to inadequate funding and support, which has led to the closure of collection repositories in extreme cases (Kemp 2015, Bakker et al. 2020, Thiers et al. 2024, Boldgiv et al. 2025). The lack of funding, combined with other factors such as stricter permitting restrictions and ethical considerations around collecting, has also contributed to a drastic decline in the acquisition of new specimens in recent years (Prather et al. 2004, Gardner et al. 2014, Daru et al. 2018, Malaney and Cook 2018, Cook and Light 2019, Rohwer et al. 2022), with these declines forecast to continue (Forbes et al. 2025a). Continued collecting is essential for maintaining temporal records to measure change and predict spatial and temporal trends, which is critical for conservation, management of ecosystem services and policy (Daru et al. 2018, Bakker et al. 2020, Forbes et al. 2025a).

Although there have been calls for observation-based occurrence records, such as photos and audio-recordings, to replace traditional specimen collection (Minteer et al. 2014), physical specimens provide other types of information, such as DNA, pathogens, heavy metals, stable isotopes and the opportunity to examine microscopic characters, not available with observational data sources (Culley, 2013, Meineke et al. 2018, Nachman et al. 2023). They also serve as verifiable resources for future studies and yet-to-be developed technologies.

As the use of natural history collections continues to grow while funding declines, it is increasingly important to re-evaluate collection strategies to sustain and strengthen the role of natural history collections as critical research infrastructure capable of addressing future biodiversity challenges and emerging scientific questions (Miller et al. 2020, Forbes 2025a). To date, specimen collection has been largely driven by the specific interests of researchers, particularly for taxonomic research, and geographic proximity, which has introduced biases to collections (Hortal et al, 2015, Daru et al. 2018, Wilcox et al. in press). But even attempts at general collecting can result in unrepresentative collections (Bakker et al. 2020, Miller et al. 2020). Such non-random collecting introduces gaps into biodiversity data, particularly contributing to the Wallacean shortfall, defined as incomplete knowledge about species distributions (Lomolino 2004; Hortal et al. 2015). These gaps can bias certain types of analyses based on herbarium records (Heberling et al. 2019, Lombardi et al. 2024), limiting our ability to effectively manage biodiversity.

To obtain more representative natural history collections it is important to identify collection gaps and develop new approaches for specimen acquisition (Meineke et al. 2018, Heberling and Isaac 2018, Cornwell et al. 2019, Lombardi et al. 2024, Forbes et al. 2025b), ideally ones that are also cost-effective. However, practical solutions for implementing such strategies and achieving collection targets are still lacking. Here we present an approach to harness the reach of citizen scientists on the iNaturalist platform (https://www.inaturalist.org/; accessed on 5 November 2025), in particular observation-based occurrence records, which have grown rapidly in recent years (Troudet et al. 2018) even as traditional specimen collecting has declined, to aid in specimen collection. iNaturalist is a free web-based and mobile app citizen science platform for recording and sharing biodiversity information. It aims to help people learn about nature while generating data useful for science. It comprises a network of users who share observations (mostly photographs but also audio recordings) and associated metadata, such as time observed and geolocation. Identifications are made by other users and/or an automated species identification tool which employs a computer vision model trained on iNaturalist's existing database of observations. iNaturalist has grown exponentially since its launch in 2008 with over 280 million observations of over 540 000 species by close to 4 million users (as of November 2025).

There have been suggestions that iNaturalist and the reach provided by citizen scientists could be leveraged to enhance and facilitate specimen collecting; for example by linking field-collected data, such as images and habitat, to specimens (Heberling and Isaac, 2018), as well as aiding in collection planning (Rosa et al. 2022, Deitsch et al. 2024, Mesaglio et al. 2025, Wilcox et al. in press). However, its use for guiding specimen acquisition remains underdeveloped. Here we present a cost- and time-saving method to target specimen collecting of uncollected taxa by using iNaturalist Projects (https://www.inaturalist.org/projects), which collate and group taxon observations using a set of user-defined rules. It is customisable by taxon, time period, location and research priority. We provide a proof-of-concept case study illustrating the benefits of iNaturalist for co-ordinating specimen acquisition.

Material and Methods

Case study

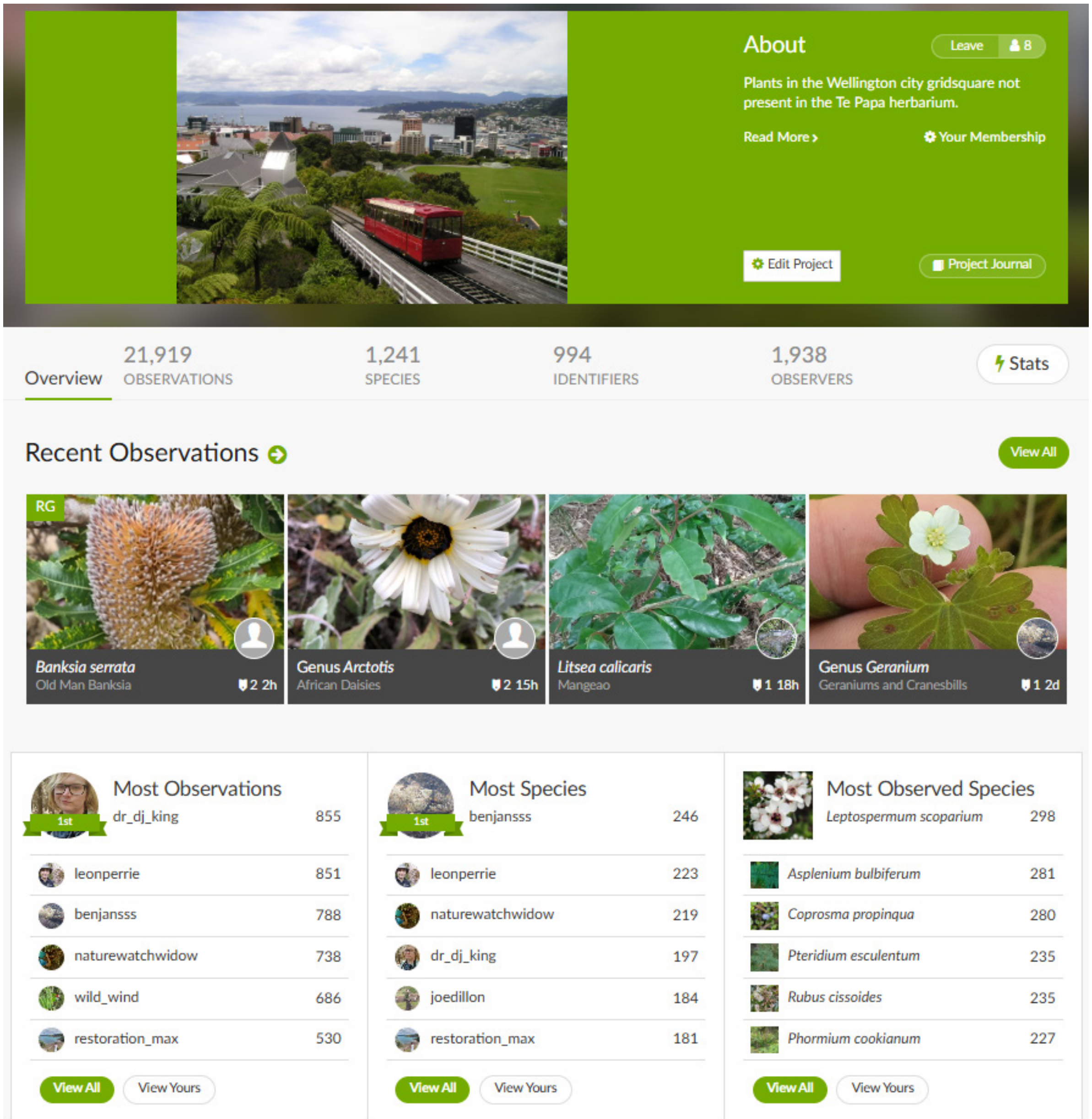
As a proof-of-concept of using iNaturalist to guide local collecting by the WELT herbarium of the Museum of New Zealand Te Papa Tongarewa in Wellington, New Zealand, we set up an iNaturalist Project in 2020 called *Wellington grid uncollected plants* (Fig. 1; https://www.inaturalist.org/projects/wellington-grid-uncollected-plants).

This project was restricted to vascular plants. General collecting by WELT is framed by a 20-minute grid of latitude and longitude through most of the country, except a 10-minute grid is used around Wellington. Consequently, the iNaturalist Place for the Project was a polygon with boundaries of latitudes 41.16667°S and 41.33333°S and longitudes 174.66667°E and 174.83333°E, which includes most of Wellington city (Fig. 2).

To avoid repeating recent collections from the area defined by this Place, we searched the museum's collection database on the 25 November 2020 for specimens collected after 1999 from the same area. This was used to generate a list of 379 species, which were then added to the 'Exclude Taxa' field in the exclusion filter of the Project. These additions were done manually, but it has since become possible to import a list of taxa into a Project's exclusion filter using iNaturalist's web application programming interface (API) (Appendix 1).

The exclusion of already collected taxa means that the observations remaining in the Project, whether they pre-dated the Project's creation or were made subsequently, were of taxa not collected from that area after 1999. This allowed targeted collecting, focused on adding specimens of species unrepresented in the WELT collection by recent material. Further refinement of this target list is also possible through the application of filters on the Project page. For example, searches can be restricted to Research Grade taxa (those that are verifiable with at least two identifications and where two thirds of identifications agree), to introduced or native taxa or to the time of year observed. Observations of target species can be limited to a subset of the target Place by zooming

Figure 1. Screenshot of the project page for the case study iNaturalist Project *Wellington grid uncollected plants* summarising observations of taxa not yet collected for the WELT herbarium.



in on an area of interest, such as a particular reserve or suburb (Fig. 3), and collection trips planned to obtain all uncollected plants in the vicinity.

As subsequent collections were made, the species they represented were added to the exclusion filter, honing the Project's observations to species that remained uncollected.

Results

Since the initiation of the *Wellington grid uncollected plants* Project five years ago, specimens of an additional 216 taxa have been added to WELT for the first time from the focal area (other species were already represented by pre-2000 specimens from the region). This represents 17% of the 1296 vascular plant taxa now collected from the area. Many of the new collections were weed species as we did not have a permit for collecting native species from reserve land. These new collections bring the total number of species from the focal area and time period that are represented in the herbarium and now excluded from the Project to 587. Furthermore, 80 specimens were the first national record of a species held by WELT (Table 1). The numbers of specimens, species newly collected for

Figure 2. Screenshot of the map of observations (green pins) of uncollected taxa for the case study iNaturalist Project *Wellington grid uncollected plants*. The orange box shows the border of the target location. The most recent observations within the Project are shown on the right.

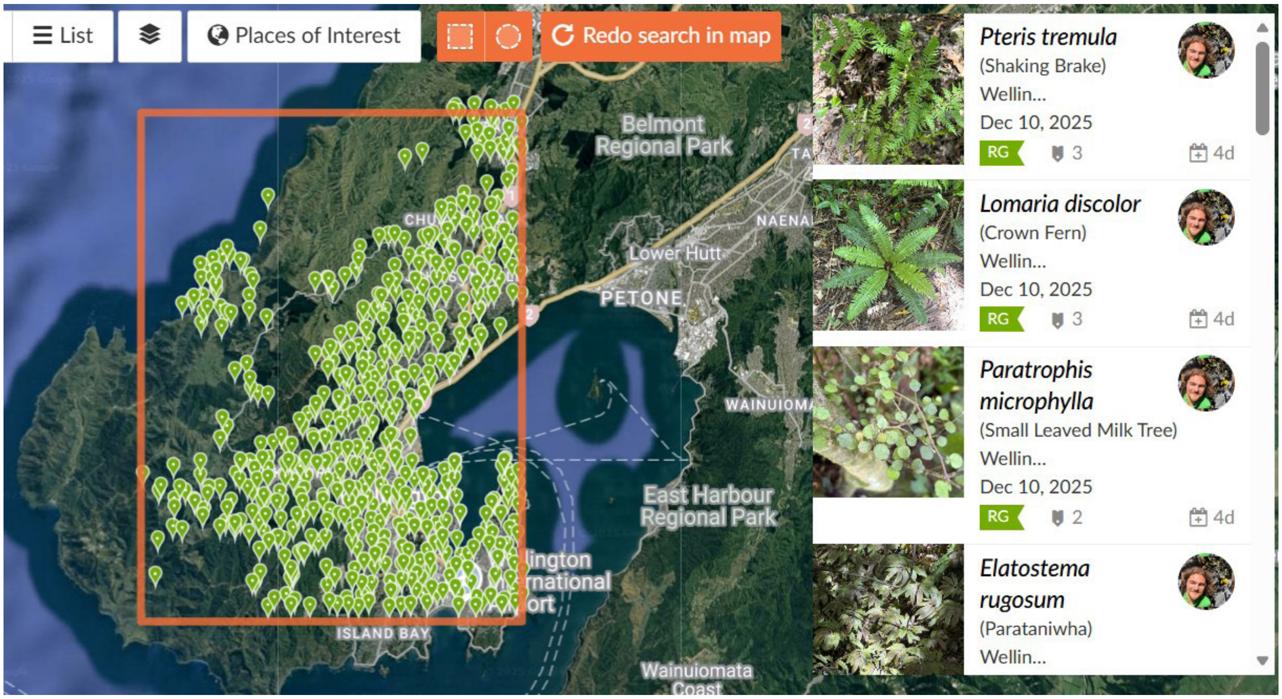


Figure 3. Screenshot of the map of a selected location (orange box) within the target area for the case-study Project *iNaturalist Wellington Grid Uncollected Plants*, showing precise locations of observations (green pins). The most recent observations within the Project appear to the right of the orange box, and the top observation (*Danthonia decumbens*) has been selected to display its details. Clicking on individual observations provides additional information, such as additional photos, observation notes, identifiers, and the precision of the mapped location.

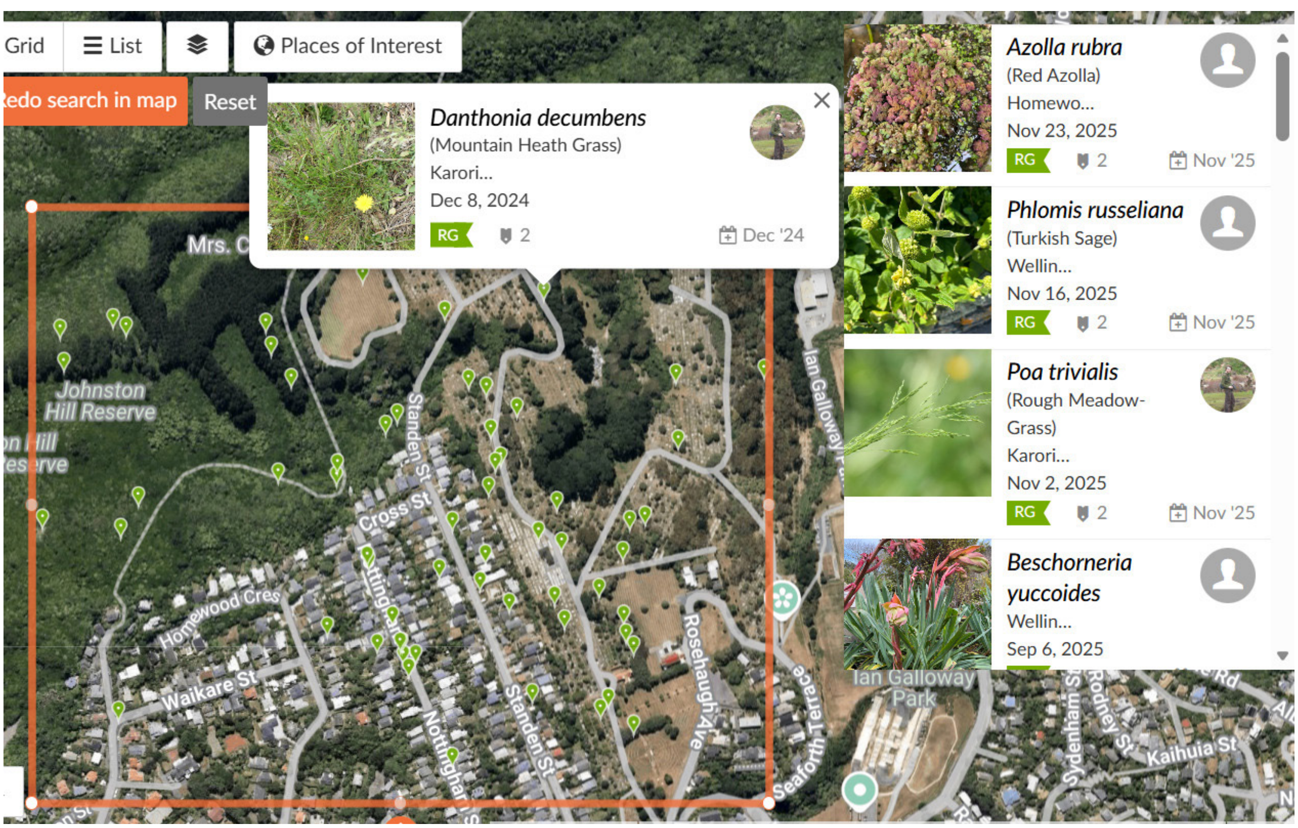


Table 1. Vascular plant collections for the WELT herbarium of the Museum of New Zealand Te Papa Tongarewa from within the Wellington 'grid' polygon defined by 41.16667°S to 41.33333°S and 174.66667°E to 174.83333°E.

Time frame	Specimen lots (total)	Taxa newly collected for WELT from the Wellington grid	Taxa newly collected for WELT from New Zealand
All years (total)	4355		
2021-2025	675	216 (32.0%)	80 (11.9%)
2016-2020	156	49 (31.4%)	15 (9.6%)
2011-2015	168	26 (15.5%)	5 (3.0%)
2006-2010	318	66 (20.8%)	12 (3.8%)
2001-2005	51	2 (3.9%)	1 (2.0%)

the map square and first national collections by WELT for a species increased substantially during the Project compared with previous five-year increments (Table 1).

We found this Project useful for planning collecting trips because we could target regions within the Place with observations of multiple uncollected taxa. Being able to check photographs of observations was valuable for confirming the identification of the taxa prior to field work (as even Research Grade identifications can be incorrect; López-Guillén et al. 2024) and for ensuring that flowers or other key diagnostic features were present. The option to contact observers was also helpful for obtaining additional information not available from the observation itself, such as site accessibility and whether it was located on private or public land.

As of 12 December 2025, there were 10 770 observations of 826 wild vascular plant species at Research Grade level still uncollected for WELT within the *Wellington grid uncollected plants* Project. Many of these remaining uncollected species are not straightforward to collect, such as plants on private land and native species only found in reserve land where collection requires a permit. Some observations also represent clearly planted individuals that were not marked as cultivated (our focus is on wild plants). Although the remaining uncollected plants observations were made by 1161 observers, around half of these (5486 observations) were made by the top 20 observers, and over a third (3853) by the top 10 observers.

As a counter comparison, herbarium specimens of 13 species added to WELT since 1999 are not represented by iNaturalist observations from the focal area. Of these, six are rare native species that are not indigenous to the region but were cultivated in specialist gardens and have since begun self-propagating locally. The remaining species are either very rare in the region, with few or no iNaturalist records from the surrounding southern North Island, or are difficult to identify reliably from photographs.

Discussion

As the world faces a biodiversity crisis, there have been calls for improved ways to maintain, focus, and coordinate natural history collection activities to provide a critical baseline for tracking organismal responses to global change (Bakker et al. 2020, Forbes et al. 2025a). Integrating collection strategies with the on-the-ground surveillance of citizen scientists through the iNaturalist platform offers a practical tool to enhance the collecting process, particularly addressing the Wallacean shortfall of incomplete knowledge of geographic distributions (Hortal et al. 2015).

Our *Wellington grid uncollected plants* Project clearly demonstrates the benefits of using iNaturalist to guide targeted collecting. We increased both the number of collections and the number of newly-collected species over the five years that the Project has been active, with threefold to hundred-fold increases in the number of newly-collected species compared with previous five-year periods. The five-year period preceding the Project had a similar proportion of novel species additions, although far fewer additions overall. During that early period, herbarium staff prioritised collecting weeds, particularly uncommon weeds, and 2020 was marked by COVID-19-related lockdowns that saw increased local collecting because of limited collecting opportunities in other regions. There are other confounding factors that were not controlled for in our study, such as changes in staff, shifts in museum priorities and changes to collecting permit requirements. Regardless, we found the Project to be a tool that improved our collecting efficiency by supporting collection planning and reducing some of the chance elements inherent in field collecting.

It is straightforward to create multiple iNaturalist Projects that are tailored to cover different collection strategies, spatial areas, taxa and time periods. Collection strategy can be as simple as our example of one specimen per species within a defined area and timeframe to more sophisticated data-driven approaches, such as that proposed by Forbes et al. (2025b) where information science and decision theory are used to determine collection priorities.

Since setting up the *Wellington grid uncollected plants* Project we have started other iNaturalist Projects for vascular plants, including one covering all of New Zealand and excluding species that already have specimens in the major New Zealand herbaria, with the aim of ensuring every species observed in the country is represented by a specimen in a New Zealand herbarium (https://inaturalist.org/projects/aotearoa-new-zealand-herbaria-uncollected-species).

Although our *Wellington grid uncollected plants* Project was based in the same city as the herbarium for which we were collecting, allowing for impromptu collecting trips, the approach outlined here would also be valuable for regions located farther from collection repositories. For example, collection trips can be targeted towards subregions within a Place with a high number of uncollected taxa. Trips can also be scheduled to follow Bioblitz events, such as the City Nature Challenge or locally organised surveys, when large numbers of up-to-date Research Grade observations are uploaded. Such strategic planning will likely save time and money by increasing collection efficiency.

The majority of the collections in our case-study Project were made by the authors, who live locally within the Project boundary. However, we see potential to use our approach to engage more closely with iNaturalist Users, including to assist with collecting. We have successfully recruited observers to collect interesting specimens from other regions in New Zealand. Most observations in our case-study Project were made by relatively few of the observers, which is typical for iNaturalist, where users often focus on their local area and develop taxonomic specialisations (Di Cecco et al. 2021). Such 'super-users' could be approached to join Projects and contribute collections.

Further opportunities to engage with citizen scientists, and provide learning experiences, could be developed by linking Projects with education providers and local interest groups, such as botanical societies, enabling the sharing of collection priorities.

Current limitations and potential future improvements

Despite the promise of using iNaturalist Projects to aid specimen collection, there are several shortcomings, and there are opportunities to improve the process that we have outlined. Our case study examined vascular plants, a mostly conspicuous, readily observed group for which many species are identifiable from photographs. The approach we propose is less useful for taxa that are rarely observed by iNaturalist Users or that are difficult to identify from photos, such as invertebrates or bryophytes that require examination with a microscope (Barbato et al. 2021). It is also likely to be less useful in areas with low population densities or poor engagement with iNaturalist. iNaturalist observations have been shown to demonstrate spatial biases (Geurts et al. 2023, Mason et al. 2025), which in some regards are likely similar to the biases present in collections. For example, greater numbers of both observations and collections come from areas with higher population density and from locations that are easier to access, such as roadsides and walking tracks. However, engaging with citizen-scientist collectors may also help overcome some spatial biases because a diverse pool of collectors can cancel out individual collector-specific tendencies (Schmidt et al. in press).

When setting up a new Project there are constraints around the use of Places. There are numerous existing Places in iNaturalist, such as countries, counties and districts that can be used to define an area of interest. But when an area of interest is not available as an existing Place it can only be defined by a User who has made at least 50 verifiable observations and only if the new Place has fewer than 200 000 observations at the time of creation (Places with >200 000 observations must be created by iNaturalist staff).

The process of including or excluding large numbers of taxa in a Project is not straightforward. The bulk upload of taxa through a spreadsheet is currently not possible, except by modification of the Project's inclusion/exclusion rules using the API (Appendix 1). The ability to bulk upload taxa into projects was requested by iNaturalist Users in 2019 but is not a priority and remains under review with the iNaturalist developers as of December 2025.

At present the iNaturalist app is less useful for engaging with Projects than the web portal but it is the app that is more likely to be used in the field for making observations. When viewed through the web portal, qualifying observations of Users that have joined a Project have a tag on their page indicating that they meet the criteria for the Project. However, this is not visible in the app. Having this information available in the app would be useful for determining in real time whether an observation represents a target taxon, potentially allowing specimens to be collected immediately.

To keep a project up to date the project rules must be regularly revised as new taxa are collected. We found that the simplest approach is to manually add newly collected taxa to the excluded-taxa list on the Project page. A reliable system is essential for tracking new species additions and ensuring that the exclusion list remains current, particularly when multiple people are involved in specimen collection and processing.

Lastly, taxonomic name changes are not automatically updated in the included/excluded taxa list, meaning that these lists can quickly become outdated. When a scientific name changes in iNaturalist the old name remains in the list followed by '! Inactive Taxon' and the new name needs to be manually added.

Conclusion

The strategy presented here for guiding the collection of new specimens provides a much-needed practical tool for obtaining new field collections of target taxa and addressing the Wallacean shortfall. It uses the widely adopted iNaturalist platform to harness the reach of citizen scientists, providing "eyes on the ground" for the discovery of collection targets. The approach can bring cost and time efficiencies to collecting, and it can be tailored to specific needs by including or excluding taxa and adjusting parameters such as spatial area, taxonomic group, or season. Furthermore, it creates opportunities to engage citizen scientists in building natural history collections, which is an essential step in ensuring that these collections are valued by the public and supported for their long-term survival.

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Appendix 1. Setting up an iNaturalist collection Project

1. **Sign up for a free iNaturalist account**. https://help.inaturalist.org/en/support/solutions/articles/151000195690-how-to-sign-up-for-an-inaturalist-account
2. **Set up a collection Project:** https://help.inaturalist.org/en/support/solutions/articles/151000176472
3. **Set included taxa.** We restricted our case study Project to vascular plants.
4. **Include the location of the project**. Either use an existing Place or create a new Place using a KML file (https://help.inaturalist.org/en/support/solutions/articles/151000175019-how-to-make-a-place-on-inaturalist).
5. **Define the taxa excluded from the Project**, such as those already collected, by manually entering them individually or importing them as a batch. To import a batch, such as a species list exported from GBIF, a .csv file of scientific names must first be uploaded as a list (https://www.inaturalist.org/projects/vermont-atlas-of-life/journal/28764-tech-tip-tuesday-creating-lists). This has the advantage that differences in taxonomies can be corrected through the import process. Species imported into the list can then be excluded through modification of the project using the iNaturalist application programming interface (API) with code available in a Jupyter workbook on the GitHub repository https://jumear.github.io/stirpy/lab?path=iNat_update_project.ipynb under the BSD 3-Clause License. To include/exclude the taxa in the list:

A. run the first two cells of code.

B. in the third code cell:
- set the project_id to the project identification number of your iNaturalist Project.
- get your JWT (JSON Web Token, used to authenticate your request to modify the project via the API) by opening https://www.inaturalist.org/users/api_token in your browser while logged into iNaturalist. Copy the string between the second set of “” and use it to replace j.w.t in the line jwt = 'j.w.t', Then run the code in this cell.

C. in the fourth cell, modify the source rules to exclude taxa from your exclusion list (replace the number below with the number of your own checklist): source_rules['taxon']['exclude']['ids'] = await get_taxon_ids_from_list(4552232). Then run the code. It is also possible to import a list of included taxa to target in the same way by changing the code from [‘exclude’] to [‘include’].

D. Run the code in the fifth cell, which will give a summary of the rule changes to be applied. The changes can then be applied by running the code in the cell starting ‘# Execute the request(s)’

The project will now only show the observation of species not on the list of excluded taxa. The map view shows the location of these observations and individual observations can be selected to view photos and details of the observation, such as location and date.

6. **Update the project as new collections are made.** This can be done either by manually adding each species name to the excluded taxa list on the project page, or by importing them as a .csv into the List of excluded taxa then modifying the project page through the API, as described in step 5 above.